

Assessing Key Challenges, Strategies, and Policies Towards Sustainable Infrastructure Development in India

Nithyashree M.C¹ and Thanu H.P²

¹Research Scholar, Department of Construction Technology and Management JSS Science and Technology University (SJCE), Mysuru, Karnataka, India 0009-0004-5123-527X

²Assistant Professor, Department of Construction Technology and Management, JSS Science and Technology University (SJCE), Mysuru, Karnataka, India 0000-0003-0789-4820

Abstract—India has made remarkable progress in developing its infrastructure in recent years. Incorporating sustainable practices in infrastructure helps in overall development by considering all three 3 factors (economic, social, and environmental). India needs sustainable infrastructure to support its development. This includes renewable energy, transportation, waste management, urban planning, and building construction. However, the country is facing challenges in the development of this infrastructure even though the Indian government has taken steps to address this, such as the Back to Growth implementation and the PM Gati Shakti National Master Plan. This study aims to understand the challenges faced in the development of sustainable infrastructure and assess the various policies and strategies adopted in India and abroad to mitigate them through a literature review. It also provides recommendations to strengthen the existing policies in India to address these challenges. This research contributes to the existing body of knowledge, fills the gaps in the literature, and serves as a valuable resource for policymakers on sustainable infrastructure development in India. Adopting proper policies, strategies and their promotion helps in mitigating these challenges and acquaint various stakeholders.

Keywords— Sustainable infrastructure, Challenges, Policies, Strategies, Development, India.

I. INTRODUCTION

Sustainability means meeting the needs of the present without compromising the ability of future generations to meet their own needs. With the increasing threat of climate change and the reduction of renewable resources, the world is seeking ways for development. So, there is a need for sustainable development in various domains. Sustainability development requires an integrated approach to environmental concerns and socio-economic development [1]. Sustainable development goals form the framework for improving the lives of population around the world and mitigating hazards or manmade effects of climate change. The country's environmental performance directly affects the health of society therefore there is a necessity of integrating measures to prevent climate change with adoptable development frameworks. The success of such sustainable frameworks generates a better economy, which leads to the welfare of the community.

This green energy use and green practice implementation in various projects enhances environmental sustainability and reduces health expenditure without compromising economic growth [2].

For sustainable development in the General Assembly of the United Nations, all the countries adopted a resolution titled “Transforming our world: the 2030 Agenda for Sustainable Development”. India is also a member country and is now focusing more on sustainable infrastructure, which is a part of this agenda because it helps achieve 10 out of 17 goals [3]. An infrastructure is said to be sustainable if it is planned, designed, constructed, operated, and decommissioned in a manner to ensure economic, financial, social, environmental (including climate resilience), and institutional sustainability over its entire life cycle [4].

India is the largest populated developing country [5] and demands social, economic, and environmental development. To achieve this, sustainable infrastructure is one of the key ways for the overall development of the country considering all three pillars of sustainability. The government's commitment to addressing these challenges is reflected in various policies, programs, and initiatives within the country. National development banks contribute to infrastructure development by providing financing resources that address infrastructure challenges faced by India requiring mobilization of nearly \$3.5 trillion by 2030. Harnessing the potential of renewable energy is directing their activity toward sustainable infrastructure [6].

At the progress stage of sustainability growth in India presenting the budget of 2023-24 focuses on sustainable infrastructure through capital outlay increased by 33% to 10 lakh crores. To boost investment in the renewable energy sector through various policies, Indian Renewable Energy Development Agency Limited (IREDA) gets “infrastructure finance company” status from RBI [7]. India is emerging as the fastest-growing economy in the world and is currently Asia's 3rd largest economy by GDP. Environmental consequences have a serious constraint on natural resources, driving energy and commodity prices. Thus, the concept of a green growth agenda reduces the quantity of resources required to support economic growth which leads to the enhancement of social equity and job creation [8]. This study embarks on an exploration of the sustainable infrastructure development policy landscape. It reveals various policies, goals, and actions undertaken by India and other countries to address the challenges faced in the development of sustainable infrastructure and strengthen existing policy frameworks through the promotion of the right strategies.

II. LITERATURE REVIEW

A. Sustainable Infrastructure and its Need

The term infrastructure refers to the fundamental organizational, physical, and structural components and amenities that are necessary for the functioning of a society [9]. However, sustainable infrastructure takes a step further by embracing sustainability concepts, which cater to address current needs without jeopardizing the capacity of future generations to address their own [10]. Sustainable infrastructure is defined as infrastructure that supports sustainable development objectives [11]. In addition to offering populations basic needs, sustainable infrastructure seeks to reduce its negative effects on the environment, save resources, and make communities more resilient to natural disasters [12]. To lessen environmental effects and lengthen lifespan, entails the thoughtful and responsible use of natural resources, increasing the application of eco-friendly materials, and the integration of smart technologies [13]. As we become more aware of the ecological impact of the construction industry, it's becoming increasingly important to prioritize sustainability in infrastructure. This means designing and building structures in a way that conserves resources for future generations, while also meeting environmental, societal, and economic sustainability standards [13].

As the population grows and travel time is to be reduced, there's a greater need for affordable and fast transportation. However, in the past, little thought was given to the environmental impact during the development of transportation systems. Today, stakeholders are prioritizing sustainable transportation infrastructure, especially in fast-developing countries like India [14]. Achieving a strong, dependable, resilient, and technologically advanced road network in India by 2030 requires sustainable infrastructure [15]. Cities like Old Town (Bhubaneswar), struggle with unplanned development, congested roads, poor waste management, and depleting water sources. Similarly in Pune urbanization, and climate change impacts make sustainable water infrastructure in India essential [16][17].

Overall, sustainable infrastructure in India is vital for inclusive growth, environmental stewardship, and energy efficiency. It aligns with global sustainability principles and smart technology advancements in construction and development [18]. Providing sustainable infrastructure is critical for infrastructure growth in the renewable sector to reduce the country's carbon footprint and focus more on an environmentally friendly energy mix.

B. Role of Policies and Strategies in the Development of Sustainable Infrastructure in India

Policies and strategies play a critical role in shaping the development of sustainable infrastructure in India. Various sectors such as energy, urban development, and industries have been focusing on sustainability, driven by policies that advocate for the minimization of construction materials, energy conservation, and the use of waste materials [13]. Furthermore, sustainable development is essential for the Indian economy's growth projections, and structural reforms incentivizing private investment highlight the importance of policy frameworks [18]. Policies provide a framework and guidelines for decision-making, resource allocation, and coordination among various stakeholders. Effective policies help in the adoption of sustainable practices, and technologies and ensure compliance with environmental standards. Well-designed policies can address the challenges of limited infrastructure expansion, lack of integration among transport systems, and multiple institutions with different mandates. Policies prioritizing sustainable development can help bridge the gap between demand and supply of infrastructure, improving overall transport quality [19]. Therefore, policies act as guiding principles to ensure the integration of sustainable practices in infrastructure development in India.

C. Efficiency and Effectiveness of Policies and Strategies in India

The Indian government has developed and implemented important policies to support sustainable infrastructure development. NITI Aayog was formed by the government of India to oversee the adoption and monitoring of SDGs in various states and Union territories. They periodically collect data and rank them based on their achievement in attaining Sustainable development goals to create healthy competition between them. One of their key initiatives is the integration of green building technologies to tackle climate change and reduce carbon emissions. This aligns with the Smart Cities project and SDG-2030 goals [20]. Furthermore, the government has made it mandatory for public and private sector firms to contribute to environmental and societal needs through Corporate Social Responsibility (CSR), which enhances infrastructural development and promotes sustainable growth [21][22]. Additionally, the focus on Sustainable Development Goals (SDGs) emphasizes good health, well-being, access to clean energy, and state-of-the-art facilities in redeveloping industrial townships, aligning with the vision for a healthier and more inclusive space [23].

The efficacy of the initiatives designed to encourage sustainable infrastructure development in India has varied [24] [25]. Problems still exist since there aren't enough funds being allocated to the construction of green infrastructure. India is ranked 3rd in LEED sustainable construction certification and area wise (Gross Square meters) there is a huge gap in green construction among states in India [26]. India has been ranked 112th out of 166 countries in achieving sustainable development goals in the year 2023. When compared to SDG 9 with other SDGs it is noticed that SDG 9 has the highest number of aspirants whose score is between (0-49) [27]. The current assessment tools used to measure a building's sustainable performance are inadequate in addressing economic and social impacts, resulting in a lack of fully integrated assessment tools [28][29]. Overall, even if there has been improvement, a long way to go before truly sustainable infrastructure is achieved as it faces various challenges such as Rapid urbanization, limited expansion of transportation infrastructure, lack of integration among major transport systems, and scarcity of natural resources are some of the major challenges faced by Indian cities [19][30][31]. More than half of India's urban infrastructure needs till 2030, including housing, electricity, transportation, water, and waste management, have yet to be developed. A comparative study across the United States, India, and Afghanistan reveals that knowledge gaps, high material costs, insufficient training, and government policies are barriers hindering sustainable practices in India [32]. India lags behind other countries in sustainable infrastructure development, especially in health, education, and vocational training [35]. India faces challenges in sustainable infrastructure development due to disputed areas with China. Resolving disputes peacefully, following international law, and prioritizing local livelihoods can ensure continued progress [33]. This shows that there is a need for India to address these challenges.

To overcome these challenges, urban planners in India are incorporating green infrastructure like urban farms and forests. Promoting the usage of alternative building materials to construct structures that can be environmentally friendly [37]. However, practical implementation remains a hurdle [14]. Developing sustainable transportation infrastructure in India requires consideration of factors such as traffic density, driver behavior, road design, and regulatory changes, instead of just focusing on cleaner fuel and road materials [10]. Up gradation of electrical grids, transitioning away from private vehicles, improving municipal water systems, and future-proofing infrastructure against climate change are the areas that India must focus on. Technology plays a crucial role in enabling sustainable infrastructure by promoting institutionalization and large-scale influence on lifestyle. Promising inventions, integrating smart

functionality and environmental conservation measures can help address these challenges, which will be crucial for India's sustainable infrastructure development.

Countries like Australia, the Netherlands, Sweden, the United Kingdom, and the United States of America are exploring ways to reduce carbon emissions in infrastructure construction through policy-driven initiatives and project-level actions [36]. Ethiopia, Japan, and the USA are implementing sustainable blue-green infrastructure to enhance water management, biodiversity, climate resilience, and urban development, benefiting their populations and ecosystems [35]. To improve sustainability and efficiency, efforts are being undertaken to incorporate innovation and smart infrastructure planning [13]. To satisfy environmental, societal, and economic needs, infrastructure sustainability is also acknowledged as being necessary across a range of industries [18]. Guiding policy development in India is crucial due to the rapid growth of road infrastructure [21]. Continuous cross-disciplinary study and knowledge sharing will be essential for sustainable infrastructure development. A new vision of India to become a developed country by 2047 (Amrit Kaal) has increased focus on green and sustainable growth which in turn benefits sustainable infrastructure development in India [36].

III. STATEMENT OF PROBLEM

India is the world's fastest-growing and most populous developing country, making it challenging to develop sustainable infrastructure. Achieving sustainable development goals is critical to India's long-term vision of economic, social, and environmental integrity. However, the path to the development of sustainable infrastructure in India faces numerous challenges in various areas. Despite having developed and implemented various strategies and policies for sustainable infrastructure, there is an urgent need to evaluate the policies, strategies, and challenges faced in this endeavor. India's complex, diversified socioeconomic and environmental scenario presents a unique opportunity and problems that require in-depth analysis.

IV. OBJECTIVES OF THE STUDY

- To determine the challenges faced during the development of sustainable infrastructure in India.
- To analyze various strategies and policies that India and other countries have adopted to mitigate these challenges and promote sustainable infrastructure development.

V. METHODOLOGY OF THE STUDY

A comprehensive search was conducted across various databases for articles, reports, and government publications on sustainable infrastructure and green infrastructure. The inclusion criteria were studies and reports that focused on sustainable infrastructure development strategies and policies in India and other countries as well. A narrative synthesis was conducted to analyze the status, challenges, and best practices for sustainable infrastructure development across various sectors, such as energy, transportation, buildings, etc.

VI. RESULTS AND DISCUSSION

India's progress towards establishing sustainable infrastructure is crucial on a global scale. The policies developed in India will play a significant role in transforming the country into a developed nation by 2047. However, India faces challenges in developing sustainable infrastructure while balancing all three pillars of sustainability. The strategies and challenges discussed here provide valuable insights for strengthening existing policies in India and for other nations facing similar issues.

A. Challenges faced in the development of Sustainable Infrastructure in India:

- Ineffective governance, inadequate regulatory strategies, and plans for sustainable infrastructure development: Complex bureaucratic processes, limited enforcement capacity, and fragmented policy frameworks contribute to ineffective governance and inadequate regulatory strategies.
- Resistance to change from the use of traditional methods and techniques: It often stems from entrenched practices, psychological behavior, lack of awareness, or perceived risks associated with adopting new approaches.
- Lack of organization's commitment toward sustainability: This will arise due to competing priorities, short-term financial pressures, and insufficient recognition of long-term benefits.
- Financial factors such as funding, risk of investment, and long-term benefits: Financial factors such as limited funding availability, perceived investment risks, and the difficulty in quantifying long-term

benefits often deter stakeholders from prioritizing sustainable infrastructure development, leading to underinvestment and reliance on conventional approaches.

- Lack of communication and collaboration between stakeholders: Gaps in the information and lack of transparency and accountability between the stakeholders lead to delays in the availability of data interns which affects the collaboration between the stakeholders.
- Environmental factors such as climate change, inefficient utilization of resources, and improper waste management lead to pollution and loss of biodiversity within the ecosystem: Inadequate environmental regulations, unsustainable consumption patterns, and limited awareness of the interconnectedness between human activities and environmental degradation leading to insufficient mitigation measures and conservation efforts.
- Lack of availability of data and stakeholder participation: Inadequate data collection mechanisms and insufficient engagement strategies, resulting in gaps in information and limited involvement of key stakeholders in the decision-making process.
- Incomprehensive tools for sustainable performance studies and impact assessment: This arises due to a lack of expertise, inadequate data availability, and the complexity of assessing interconnected sustainability dimensions, making it difficult to effectively measure and manage the multifaceted impacts of infrastructure projects. Social factors such as inadequate facilities, lack of health and safety consideration, and equal opportunity for the growing Indian population: This arises due to limited investment, lack of prioritization, and persistent social inequalities, which collectively hinder the provision of adequate facilities, health and safety considerations, and equal opportunities for the growing Indian population.
- Lack of focus on capacity building for technical expertise along with proper standards and guidelines: Underinvestment in training programs, resulting in a shortage of skilled professionals, coupled with a dearth of standardized protocols, leading to inconsistent implementation practices.
- Lack of consideration of all three pillars of sustainability (economic, social, and environment) during the development of an infrastructure project: The prevailing mindset prioritizing economic profitability over broader sustainability goals, leading to inadequate consideration of social and environmental impacts in infrastructure development.

B. Policies and Strategies Adopted in India:

- National Mission on Sustainable Habitat (NMSH): It is an initiative in India aimed at promoting sustainable urbanization and addressing environmental challenges related to urban development. Its strategies typically include promoting green buildings, energy efficiency, waste management, urban transportation, and Sustainable development practices. The mission focuses on reducing the environmental footprint of cities while improving the quality of life for urban residents.
- National Mission for Enhanced Energy Efficiency (NMEEE): It is a mission launched by the government of India to promote energy efficiency and conservation across various sectors of the economy. Its strategies include a combination of regulatory measures, financial incentives, capacity building, and public-private partnerships to promote energy efficiency and conservation in India.
- National Water Mission: It is a part of India's National Action Plan on Climate Change (NAPCC) launched in 2008. It aims to conserve water, minimize wastage, ensure more equitable distribution, and improve water use efficiency. Its strategies include promoting efficient water use in agriculture, rejuvenating rivers, and enhancing groundwater recharge. The mission also focuses on promoting water-saving technologies, rainwater harvesting, and creating awareness about water conservation among stakeholders.
- Clean Energy Access Network (CLEAN): It is an organization focused on promoting clean energy access in India. Its strategies involve advocating for policies that support decentralized renewable energy solutions, facilitating collaborations between stakeholders, and promoting awareness about the benefits of clean energy access, especially in rural and underserved areas, CLEAN also works on capacity building.
- National Solar Mission: This Mission was launched by the Government of India in 2010, it aims to promote the development and use of solar energy for power generation. Its strategy includes setting ambitious targets for solar power capacity installation, providing financial incentives, encouraging research and development, promoting domestic manufacturing of solar equipment, and facilitating policy framework to support the growth of solar energy in India.
- Smart Cities Mission: It is an initiative launched by the Government of India to develop 100 cities across the country making them citizen-friendly and sustainable. Its strategies include promoting economic growth, and improving the quality of life by harnessing technology, urban planning, transportation, waste

management and also emphasizes public-private partnerships and community participation to ensure the successful implementation and sustainability of smart city initiatives.

- Swachh Bharat Mission: It is an initiative launched by the Government of India to ensure cleanliness across the nation and make India open defecation-free. The strategy involves various components such as constructing toilets, promoting awareness about sanitation and hygiene, and solid waste management.
- Atal Mission for Rejuvenation and Urban Transformation (AMRUT): It is an initiative launched by the Government of India aimed at improving infrastructure and quality of life in urban areas. Its primary focus includes water supply, sewerage facilities, stormwater drains, urban transport, and green spaces/recreational areas. Its strategies involve prioritization, financing, capacity building, technology adoption, citizen engagement and also enhancing the quality of life for residents in Indian cities.
- Pradhan Mantri Awas Yojana (PMAY): It's a scheme which is the flagship affordable housing scheme launched by the Government of India. Its primary aim is to provide affordable housing to the urban and rural poor. Its strategies include subsidized loans, incentives for developers, technology use, partnerships, and also improving the living conditions of citizens, especially those belonging to economically weaker sections.
- Jal Jeevan Mission: It is an initiative launched by the Government of India aimed at providing piped water supply to all rural households by 2024. Its strategy involves utilizing technology for planning, monitoring, and implementing water supply schemes, promoting community involvement, and ensuring sustainability through water conservation measures.
- National Mission for Sustainable Agriculture (NMSA): It is an initiative launched by the Government of India aimed at promoting sustainable agriculture practices to enhance productivity, resilience, and use efficiency. Its strategies include the promotion of climate-resilient agricultural practices, soil health management, water use efficiency, market linkages, and value addition, and also contribute to environmental conservation and socio-economic development.
- Green Energy Corridor Project: It is an initiative launched by the Government of India aimed at strengthening the country's transmission infrastructure to support the integration of renewable energy sources, particularly solar and wind power. The strategy includes infrastructure development, smart grid technology, capacity building and also reducing carbon emission and promoting sustainable development.

C. Policies and strategies from other countries that can be considered for better development of Sustainable Infrastructure in India:

- Sustainability procurement policy: The guidelines for acquiring goods and services and prioritizing environmental, social, and economic considerations, aiming to minimize negative impacts while maximizing positive outcomes throughout the supply chain. It typically includes criteria such as energy efficiency, ethical sourcing, and lifestyle assessments to promote sustainability and responsible consumption.
- Local Government Financing Vehicles (LGFVs): The local Governments establish entities in some countries to raise funds for infrastructure projects and other development initiatives through debt issuance and financing mechanisms. They often operate independently from the official government budget, allowing for more flexible financing options.
- Asset recycling: This refers to the practice of selling existing government-owned assets, such as infrastructure or real estate, to private investors and using the proceeds to fund new infrastructure projects. It aims to unlock capital, stimulate economic growth, and improve the efficiency of public assets.
- Tax Increment Financing (TIF): It is a public financing tool used to fund infrastructure and redevelopment projects. It involves earmarking future increases in property tax revenue within a designated district to finance current improvements, aiming to stimulate economic development and increase property values within the area.
- Phase out coal-fired power plants: This entails the gradual closure and replacement of existing facilities with cleaner energy sources to combat environmental degradation and reduce carbon emissions.
- Extended Producer Responsibility (EPR): This is a policy framework holding manufacturers accountable for the entire lifecycle of their products, including collection, recycling, and disposal, aiming to promote environmental sustainability and waste management.
- Congestion pricing: It is a policy tool that charges fees for vehicles entering designated areas during peak traffic times, aiming to reduce traffic congestion and improve air quality in urban areas.
- Design for disassembly: This involves creating products or structures to facilitate their easy dismantling and recycling at the end of their lifecycle, promoting circular economy principles, and reducing waste.

- A framework for gender-based equality: The construction involves implementing policies and practices that promote equal opportunities, eliminate discrimination, and ensure fair representation and treatment of all genders throughout the construction industry.
- Infrastructure priority lists: This identifies critical projects for development, typically based on factors such as economic impact, public safety, and long-term sustainability goals, aiming to allocate resources efficiently and address pressing infrastructure needs strategically.
- An integrated approach to capacity building: It involves comprehensive strategies that combine training, knowledge sharing, and institutional support to develop skills and empower individuals and organizations to effectively address diverse challenges and achieve sustainable development goals.

VII. CONCLUSION

India's pursuit of sustainable infrastructure development is a challenging and intricate process that involves a mix of ambitious strategies and significant obstacles. India does not have a comprehensive policy framework for sustainable infrastructure development instead they are fragmented. Strengthening existing policies and strategies will help in enhancing their effectiveness by improving development and implementation mechanisms. This study delves into the strategies and challenges that form a crucial part of India's sustainable infrastructure development policy landscape. It highlights several critical dimensions that should be taken into account to achieve a more equitable, prosperous, and sustainable future. To accomplish this, India needs to recognize the interdependence of its economic, social, and environmental components and prioritize inclusion and equity.

LIMITATIONS AND FUTURE STUDY

The study's conclusions are based on limited data and may not reflect current developments or policy changes in sustainable development. Data availability and reliability may impact the accuracy of the analysis, particularly in certain region or sectors. Challenges in sustainable infrastructure development can be prioritized which enables policymakers to allocate resources effectively, address critical issues promptly, and formulate targeted policies that enhance long-term environmental sustainability, economic prosperity, and social well-being. A comprehensive framework for implementation of sustainable infrastructure in India can be developed which facilitates coordinated efforts among stakeholders, streamlines decision-making processes, and ensures alignment with national development goals. It provides clarity on regulatory standards, promotes innovation and technology adoption, fosters public-private partnerships, and enhances accountability, ultimately driving efficient resource utilization and sustainable development outcomes.

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